Investigation of Compatibility Between IMT-Advanced Systems Operating in Band 3300–3400 MHz and Airborne Radiolocation Radar Systems Operating in Adjacent Band below 3 300 MHz

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ABSTRACT

The last decade has witnessed a tremendous evolution in mobile technology as a result of increase in demand for new mobile services and capabilities. This growth has led to the development of IMT-Advanced and conceptualization of IMT-2020, which is still being standardized. In order to accommodate this increased demand for mobile technologies, these systems need additional spectrum. One of the bands being considered for IMT-Advanced services under WRC-15 agenda item 1.1 in addition to the existing bands is 3300-3400 MHz because low frequency spectrum (below 6GHz) is absolutely essential for and economical delivery of mobile services. However, the frequency band 3100-3400 MHz is currently allocated worldwide to the radiolocation service on a primary basis. In the light of maintaining spectrum discipline, there is need to investigate the compatibility between the IMT-Advanced system to be introduced into the frequency band and the radiolocation systems currently occupying that frequency band as well as the radiolocation systems currently occupying the adjacent frequency band both below and above. In this research paper we investigate the compatibility between IMT-Advanced systems operating in frequency band 3300–3400 MHz and airborne radiolocation radar operating in adjacent frequency band 3100–3300MHz.The Spectrum Engineering Advanced Monte Carlo Analysis Tool (SEAMCAT) was used for statistical analysis as well as to determine the probability of interference from unwanted emissions and blocking noise from the IMT-Advanced base stations which is the interfering link to the radiolocation radar system. The result showed that IMT-Advanced system will cause harmful interference to airborne radiolocation radar if the band 3300 – 3400 MHz is allocated to IMT systems.

Key words: Airborne Radar, IMT-Advanced, compatibility, Monte-Carlo, Spectrum allocation.

INTRODUCTION

In recent years, there have been high demands for high data rate communications, ultra-low latency and high reliability applications. These have led to the evolution of mobile technologies from IMT-2000 in the year 2000 to IMT-Advanced in 2008 and then to the conceptualization of IMT-2020 which is still being standardized [1]. In order to accommodate this increased demand for mobile services, the ITU World Radiocommunication Conferences 2015 (WRC-15) resolved on new allocation to mobile services and proceeded to identify the band 3 300-3 400 MHz among others for

IMT-Advanced services under WRC-15 agenda item 1.1 [2].

However, the frequency band 3100-3400 MHz is allocated worldwide to the radiolocation service on a primary basis. Moreover, Nigeria currently uses the band 3100-3400 MHz for marine radar on S-band, and it is required that IMT stations in the mobile service shall not cause harmful interference to, or claim protection from, systems in the radiolocation service [3].

In resolution 223 [4], the WRC-15 requested the International Telecommunication Union Radio sector (ITU-R) to further study operational measures to enable the coexistence of IMT and radiolocation radars in band 3300-3400 MHz and to study adjacent band compatibility between IMT in the frequency band 3300-3400 MHz and radiolocation service below 3300 MHz. In this regard, at its first African Preparatory Meeting in Nairobi, Kenya, the post WRC-15 African Telecommunications Union (ATU) commissioned a usage survey for the band 3300-3400 MHz for the purpose of establishing co-channel and adjacent band studies relevant to the African Region. This is in view of the fact that out of the 45 countries for which the band 3300-3400 MHz is identified for IMT, 33 are from the African region [7]. Thus, this band is important for Africa as it is envisaged to provide increased capacity and performance for IMT-Advanced systems.

Radiolocation radars operate by transmitting electromagnetic energy from an antenna toward objects commonly referred to as targets, and observing the echoes returned from them. The targets may be aircraft, ships, spacecraft, automotive vehicles, and astronomical bodies. Since most radar systems do not transmit and receive at the same time, a single antenna is often used on a time-shared basis for both transmitting and receiving.

For the purpose of this study, radiolocation radar systems have been classified into three categories namely:

i. Land-based radar: They are deployed on the Earth surface and used for aerospace and ground surveillance; they may usually be located in the rural areas facing towards the boundary of country, ocean surface or high-altitude targets. Land-based radar is further sub-divided into land-based radar A and land-based radar B. While land-based radar A is used for scanning both the surface of the earth and air search, land-based radar B is used only for air search.
ii. Ship-borne radar: They are used for both surface scanning and air search. Though ship-borne radars are usually used during open ocean transit, they may also be used in coastal areas. In this assessment, the ship is assumed to be at her home port which is the centre of urban zone.
iii. Airborne radar: Airborne radars are used to conduct long-range surveillance and target tracking. Aircraft carrying these radars are capable of worldwide operations. They typically are operated at about 30,000 feet (though the radar will also be in operation while climbing to and descending from nominal operating altitude). Since this radar is located at high altitude, uniform distribution of IMT-Advanced stations is assumed regardless of urban, suburban and rural zone in this assessment [12].

RELATED WORK

Radio signal interference possesses serious problems to radio communications hence the need for adequate compatibility studies before allocating frequency bands to a particular service. This is why the World Radiocommunications Conference in 2015 (WRC-15) having identified the frequency band 3 300-3 400 MHz for use for IMT systems, also requested for further studies on adjacent band compatibility between IMT systems in that frequency band (3 300-3 400 MHz) and radiolocation services operating below 3 300 MHz. Specifically, it is required to quantify the effect of unwanted emissions of IMT systems in this frequency band [3]. Since this call by ITU, there has been a few working documents [2 - 4] which are preliminary studies carried out by ITU-R study groups in Australia, USA, and Thales. [7] Is a preliminary study which only considered worst case scenario using the minimum coupling loss (MCL) approach. In [12], sharing studies between IMT-Advanced and radiolocation service in the 3400-3700 MHz bands was carried out. Besides the fact that the study did not account for band 3300-3400 MHz, there has been some changes in both IMT and radar parameters [13], [14]. Sharing studies between indoor IMT systems and radar systems in the frequency band 3300-3400 MHz was also carried out by ITU-R study group in China in 2014 [15]. It was only limited to indoor IMT systems and does not cover outdoor cases which are more critical.

The ITU-R has done significant investigation in radio system compatibility, however, while most of these studies are for frequency bands other than 3 300-3 400 MHz [16], some that are for 3300-3 400 MHz considered indoor IMT systems [15]. The few studies done on outdoor IMT-Advanced systems operating in band 3 300-3 400 MHz were preliminary studies which only considered worst case scenario using the MCL approach. However, such worst-case assumption will not be permanent during normal operation and therefore sharing rules might be unnecessarily stringent.

In this study, the outdoor IMT-Advanced system was considered. SEAMCAT simulation tool was used to obtain a statistical analysis as well as the probability of interference.

METHODOLOGY

This work was carried out in three (3) stages. It started with creating the interference scenario and selecting the appropriate propagation models (there is an ITU-R working group that develops propagation models); the second stage is determination of the systems parameters for both the IMT-Advanced systems and airborne radiolocation radar. Finally, a Monte Carlo simulation was carried out on SEAMCAT using the determined system parameters and propagation models.

SEAMCAT is a statistical simulation model that uses a method of analysis called Monte Carlo to assess the potential interference between different radiocommunication systems such as broadcasting, point to point, radars, and mobile networks [17]. It relies on repeated random sampling and statistical analysis to compute results. With repeated random generation of interferers and their parameters and sufficiently high number of trials for statistical reliability, the approach produces a much reliable results for spectrum optimization. Fig. 1 depicts a typical victim and interferer scenario for a Monte Carlo Simulation trial.

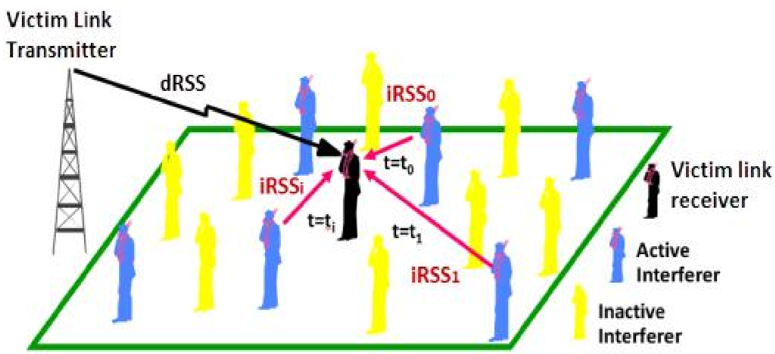
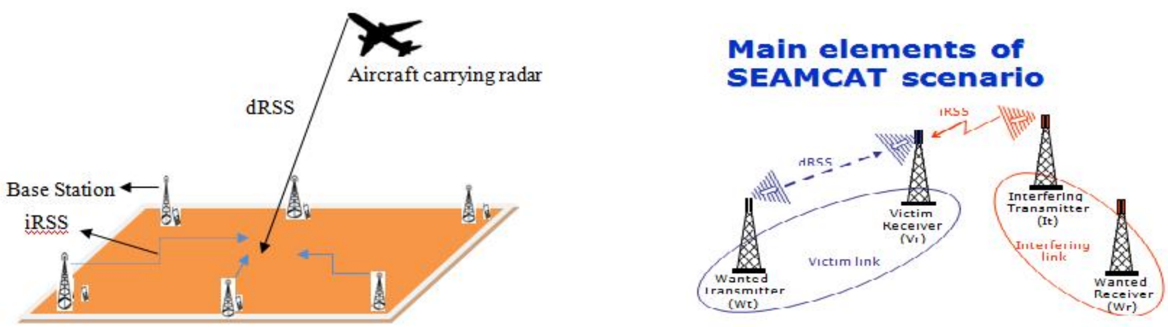


Fig. 1: Typical victim and interferer scenario for a Monte Carlo Simulation trial.

Interference Scenario

This study focuses on the interference from IMT-Advanced system to airborne radiolocation radar system. The radars which are deployed on surveillance aircrafts are typically operated at about 9 000 m in altitude. Considering the fact that most airports are situated in a suburban environment, the IMT-Advanced macro suburban deployment was used in this study. The IMT-Advanced system was setup as the interfering link while the airborne radar was setup as the victim link as shown in Fig. 2.



(a) Representation of airborne interference (b) SEAMCAT Simulation scenario

Fig. 2: Simulation experiment scenario

Propagation model

A radio propagation model is an empirical mathematical formulation for quantitative characterization of radio wave propagation as a function of frequency, distance and other conditions. It is usually developed to predict the behavior of radio links (path loss or effective coverage area) and is therefore needed for compatibility studies [17]. Selecting an accurate model for propagation losses is very important when planning a mobile radio network because using the wrong propagation model could have adverse effect in the simulation results.

In this work, the free space propagation model was used. This model describes the theoretical minimum propagation path loss achievable in free space conditions. It is appropriate to use on paths were unobstructed direct line-of-sight propagation could be expected and the scenario under investigation provides a near line of sight situation. The free space transmission path loss is given by:

$$L = 32.5 + 10\log\left(\left(\frac{(h_{rx}-h_{tx})}{1000}\right)^2 + d^2\right) + 20logf \qquad 1$$

where: h_{tx}, h_{rx} are transmitter and receiver antenna heights respectively, f is the operating frequency in MHz and d is separation distance in km.

System Parameters

The various simulation parameters are listed here.

i. Airborne Radar Parameters

Recommendation ITU-R M.1465-2 [14] Provides the characteristics of and protection criteria for radars operating in the radiodetermination service in the frequency band 3 100-3 700 MHz as shown in Table 1 below.

Table 1: Characteristics of airborne radiolocation radar system

Parameters	Unit	Airborne radar system
Modulation		Q7N
Tuning range	GHz	3.1-3.7
Tx power into antenna	kW	1000
Antenna height	m	9000
Pulse width	μs	1.25
Repetition rate	kHz	2
Compression ratio		250
Duty cycle	%	5
Tx bandwidth (-3 dB)	MHz	>30
Antenna gain	dBi	40
Antenna type		SWA
Beam width (H,V)	Degrees	1.2, 6.0
Maximum vertical scan	Degrees	±60
Horizontal scan type		Rotating
Maximum horizontal scan	Degrees	360
Horizontal scan rate		36
Rx sensitivity	dBm	-98
Protection criteria (I/N)	dB	-6.0
Rx noise figure	dB	3
Noise floor	dBm	-112
Rx IF bandwidth (-3 dB)	MHz	1
Deployment area		worldwide

ii. IMT-Advanced Parameters

Recommendation ITU-R M.2292, TS 36.101 and TS 36.104 [13,18,19] Provides the characteristics of terrestrial IMT-Advanced systems for frequency sharing and interference analysis as shown in the Table 2.

Table 2: IMT-Advanced Parameters for bands between 3 and 6 GHz

Parameters	Unit	Macro Suburban (Base Station)
Cell radius	km	2
BS Antenna height	m	25
Antenna tilt	°	6
BS antenna gain	dBi	18
Sectorization	Sectors	3
Operating Frequency	MHz	3 300-3 400
Frequency reuse		1
Antenna polarization	Degrees	Linear/±45
BS max. transmit power (5/10/20 MHz)	dBm	43/46/46
Protection criterion (I/N)	dB	-6
ACLR	dBm/MHz	-15
BS Sensitivity	dBm	-101.5
BS noise figure	dB	5
Minimum coupling loss	dB	70
Max. RBs per BS		500
Antenna pattern	[20]	
RB bandwidth	kHz	180
System bandwidth	MHz	100
BS ACS (5/10/20 MHz)	dB	46/46/43
Feeder loss	dB	3
Spurious emissions	dB	-52
	Mobile Station (MS)	
Max. transmit power	dBm	23
Antenna gain	dBi	-4
Antenna height	m	1.5
ACS (5/10/20 MHz)	dB	33/33/27
Body loss	dB	4
User terminal density in active mode	MHz/km^2	2.16/5
Indoor user terminal penetration loss	dB	20
Receiver noise figure	dB	9
OOB emission level	dBm/MHz	-17

SIMULATION

The simulation was done using SEAMCAT version 5.2.0. The simulation workspace was setup using the parameters in Table 1 and Table 2 for the airborne radar and IMT-Advanced macro suburban respectively. For the IMT-Advanced system operating in frequency band 3300 – 3 400 MHz a center frequency of 3350 MHz was used while for the airborne radar system, adjacent frequency range 3260 – 3300 MHz was considered. This is because frequencies below 3260 MHz is outside the emission mask of the IMT-Advanced system with a center frequency of 3350 MHz. At the end of the simulation, a scenario outline which depicts how both systems interact with each other was obtained as shown in Fig. 3. A workspace result was also generated which gives the desired received signal strength (dRSS), unwanted interference received signal strength ($iRSS_u$), and the blocking interference received signal strength ($iRSS_b$). These values are then used to determine the probability of interference.

The equations for the received signal strengths are as given below:

$$dRSS = P_{VLT}^{output} - PL_{VLT-VLR} + G_{VLR} + G_{VLT} \qquad 2$$

where:

P_{VLT}^{output}: Power supplied to the victim link transmitter (VLT) antenna;

$PL_{VLT-VLR}$: Path loss between VLT and victim link receiver (VLR);

G_{VLR}: VLR antenna gain; G_{VLT}: VLT antenna gain.

The $iRSS_u$ for the i-th interferere is given by equation (3):

$$iRSS_u^i = emission_{ILT}(f_{ILT} - f_{VLT}) + g_{ILT}^{pc} - \max(PL_{ILT-VLT} - G_{ILT} + G_{VLR,}MCL) \qquad 3$$

The calculation is repeated for each defined interfering link so that the $iRSS_u$ is

$$iRSS_u = 10log10(\sum_{i=1}^{n} 10^{\frac{iRSSi}{10}}) \qquad 4$$

Where:

f_{ILT} is frequency of the interfering link transmitter (ILT),

f_{VLR} is frequency of the VLR,

$emission_{ILT}$ (f_{ILT}-f_{VLR}) is the relative emission mask which is a function of $\Delta f = (f_{ILT}, f_{VLR})$,

g_{ILT}^{pc} is the power control gain for the ILT with the power control function,

G_{ILT} is the ILT antenna gain, $G_{VLR}$is the VLR antenna gain

$PL_{ILT-VLR}$ is the path-loss between the interfering link transmitter and the victim link receiver.

MCL is the Minimum coupling loss given by the system parameter definition.

The calculation of $iRSS_b$ for the i-th interferer signal is as given in equation (5)

$$iRSS_b^i = P_{ILT}^{output} + g_{ILT}^{PC} - a_{VLR}(f_{ILT} - f_{VLR}) - \max(PL_{ILT-VLR} - G_{ILT} - G_{VLR,}MCL) \qquad 5$$

The calculation is repeated for each defined interfering link so that the total $iRSS_b$ is:

$$iRSS_b = 10log10(\sum_{i=1}^{n} 10^{\frac{iRSSi}{10}}) \qquad 6$$

where:

P_{ILT}^{output}: Power supplied to the ILT antenna,

$a_{VLR}(f_{ILT} - f_{VLR})$: blocking attenuation of the victim link receiver.

The probability of interference (p_I)is then computed as follows:

$$p = \sum_{j=1}^{k} p\left(\frac{dRSS(i)}{iRSS(i)+N} < \frac{I}{N}\right) \qquad 7$$

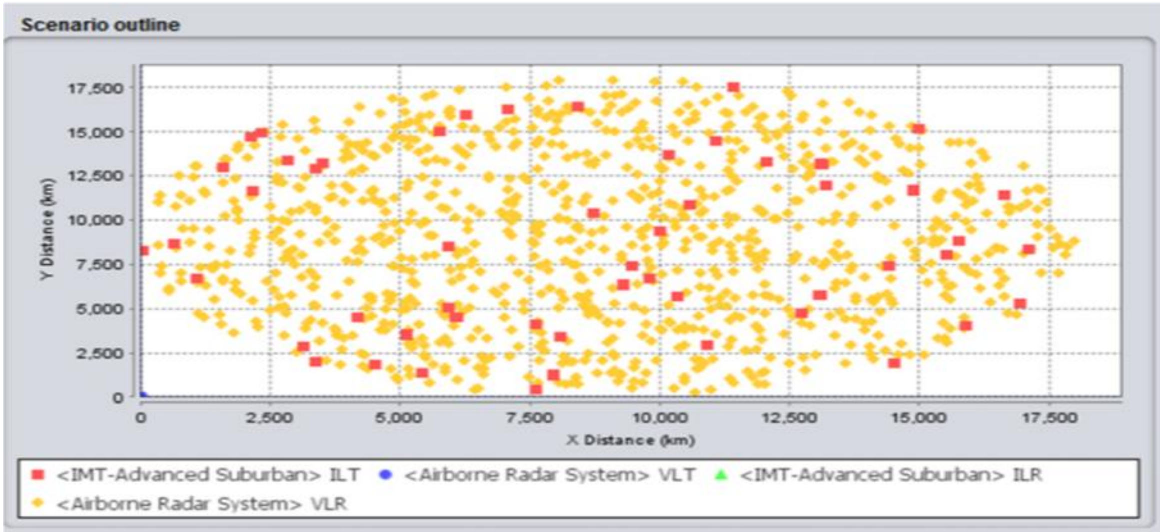


Fig. 3 Scenario outline

In the scenario outline shown in Fig 3, the red boxes represent the interfering link transmitters which in this case is the IMT-Advanced base stations; the yellow boxes represent the victim link receivers, which in this case are the targets being tracked by the radar while the blue box at the origin is the victim link transmitter, which in this case is the airborne radar.

RESULTS AND DISCUSSION

The results obtained are as shown in Fig. 5. These results show that IMT-Advanced Macro suburban deployment operating at 3300 – 3400 MHz will cause serious interference problem to airborne radar system operating at the adjacent band below 3 300 MHz.

Simulation Summary

	Mean	Median	StdDev
dRSS	-14.86 dBm	-15.52 dBm	3.24 dB
iRSSunwanted	-56.44 dBm	-56.44 dBm	0.00 dB
iRSSblocking	-36.44 dBm	-36.44 dBm	0.00 dB

(a) Obtained results

(b) Probability of interference

Fig 5: compatibility analysis results from the simulations

CONCLUSION

This work investigated the compatibility between IMT-Advanced if allocated band 3300 – 3400 MHz and Radiolocation service which is already occupying the adjacent band 3100 – 3000 MHz on primary basis. SEAMCAT was used for interference analysis and determination of interference between the two services. The study revealed that operating IMT-Advanced systems in frequency band 3300 –3400 MHz will cause serious interference problems to airborne radiolocation radar, and this could lead to serious challenges in the aviation sector. There is therefore the need for further research work on the appropriate interference mitigation techniques between IMT-Advanced system and airborne radar if this frequency band must be used.

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